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Impact of Brownfield Sites on Local Energy Production as Resilient Response to Land Contamination: A Case Study in Italy

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Abstract: The decentralization of the production sector crisis following industries in the suburbs have generated a multitude of empty containers in the medium-large Italian cities, which are abandoned, unsafe, and often dangerous for the community. From this arises the need to recover them and transform them into something else. This is not always possible or interesting for the subjects involved in the transformation. When the abandoned space is (even if only partially) polluted, then any hypothesis of transformation is stopped due to the high impact of decontamination costs, which greatly compromise the profitability of the investment. This paper deals with this issue focusing on a complex case study involving the abandoned area and the buildings of a former paint mill in the center of a typical city in the Turin metropolitan area. The suggested hypothesis is to act only on building components and external areas without any ground modification because of its contamination. Moreover, the new planned use (energy production from renewable sources to supply part of the public administration's needs) does not foresee neither a stable presence of people nor a further consumption of land. The technical analysis of community energy needs and the subsequent economic and financial study lead to a financial sustainability over a period of about 25 years.

Keywords: brownfield; economic sustainability; land contamination; energy production; regeneration; city resilience

1. Introduction

During the 20th century, between the 1950s and 1960s, Italy had rapid economic growth and technological development in the reconstruction after the Second World War. Between 1957 and 1960, in just three years, the industrial production recorded an average increase production of 31.4% [1]. This was driven by the highest development into the fields of car production, precision mechanics, and fiber-related artificial textile [2]. The industry's development needed new production plant and infrastructures for the connections. Therefore, it became the promoter of a quick change of the national physiognomy of the territory. The country landscape changed and the essentially rural and agricultural society spread in large urban and industrial suburbs. Neither coasts and small villages were spared and were turned into seaside amenities or tourist resorts to meet the new demands raised by the new industrial and urban society. In addition, entire areas were constructed to accommodate the workers' homes besides industrial sites.

Even if, on one hand, the industrial development was undoubtedly beneficial because it brought about a general improvement in the living conditions of the population thanks to the creation of new jobs and to the implementation of public services, on the other hand, it was also the cause of a wicked consumption of land. The lack of both proper general planning and standards for environmental protection led to a significant anthropization and pollution of rural landscape, which are the cause of a strong fragility of the territory today.

Nowadays, however, many industrial areas–built during those years of strong expansion–are into disuse and waste [3]. This is because, over the decades, some industries developed in the post-war period, due to the production sector crisis [4], shut down for bankruptcy, because their processes with the changing of workers' health requirements, or because the increasing fiscal pressure leaded to delocalization. From this arises the need to recover them and transform them into something else [5–7].

Too often, the areas in property of that companies were not decommissioned nor reclaimed. If the abandoned space is polluted, then any hypothesis of transformation is discarded due to the high impact of decontamination costs [2,8–11]. Today in Italy, there are many disused industrial sites so-called "brownfields" [3]. This phenomenon is not only Italian, as it affects many countries of the world [12]. In the report of the working group "Brownfield Redevelopment" of the network CLARINET (Contaminated Land Rehabilitation Network for Environmental Technologies), a project founded under the Environment and Climate Programme of the European Commission, they are defined as "brownfields": ‹‹ *sites that have been affected by the former uses of the site and the surrounding land; are derelict or underused; have real or perceived contamination problems; are mainly in developed urban areas; require intervention to bring them back to beneficial use* ›› [13].

Even if, in the United States, it is estimated that there are at least 450,000 brownfields, in Europe, the quantification of the "phenomenon" is more difficult. Only a few countries have assessed brownfield consistency, although they represent a widely recognized problem. According to a 2002 survey in Germany, brownfields are estimated to occupy approximately 128,000 hectares of land. Meanwhile, in the United Kingdom, they occupy an estimated 39,600 hectares of land, in France, 20,000 hectares, in Holland, 10,000 hectares, and in Belgium (Wallonia), 9000 hectares [12]. In Italy, however, the disused industrial areas represent about 3% of the national territory, for a total amount of about 9000 square kilometers, of which about 30% is located in the urban area [14]. To date, there is no national census of abandoned industrial areas. However, there are some surveys carried out at municipal level. An example is the "Trentametro" project drawn up by the metropolitan city of Turin [15]. In the latter, the disused industrial areas were mapped and a geo-referenced on a web platform, containing some information about each site (Figure 1). In total, more than 130 sites exist, mostly between 5000 and 10,000 square meters in size.

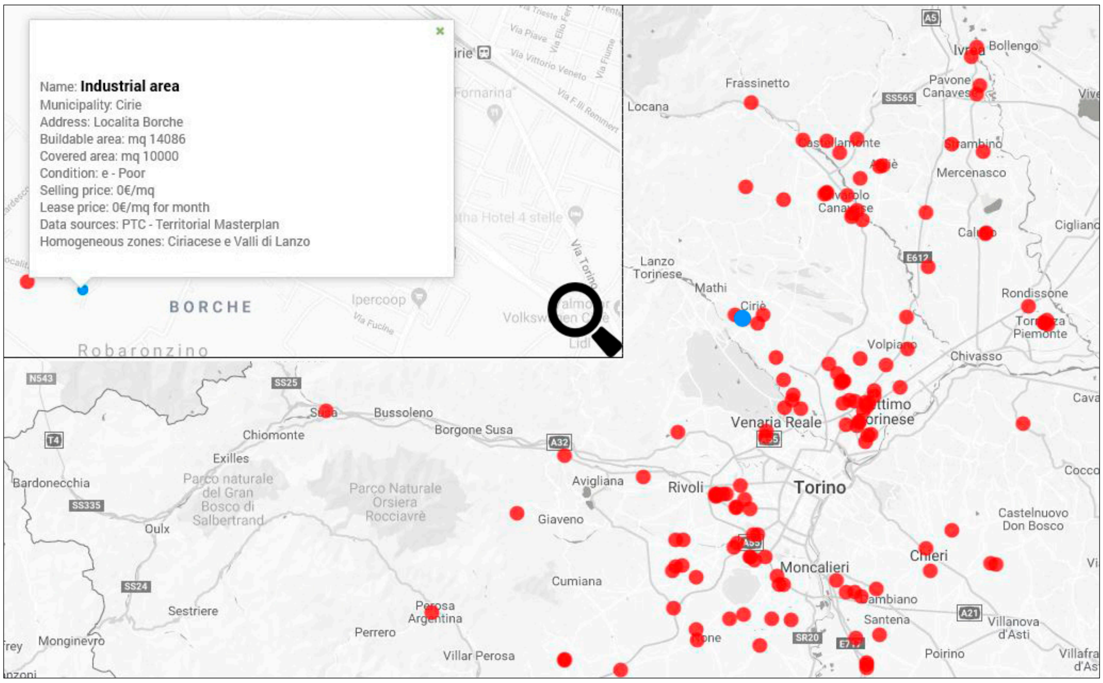

Figure 1. Extract of brownfields map of Turin metropolitan area and some short information for a single selected case [15].

Given the magnitude of the problem, it is necessary to think about adaptive policies aimed at the reuse of areas that are currently in a state of decay. The site's pollution condition greatly reduces the market value [16] and compromises the investment profitability [17]. Often, the costs for their full recovery is not compatible with the financial availability of public administrations, so to reconcile the economic constraints of the public administration with the desire to make these areas useful, it is necessary to identify interventions that do not deal with their full recovery, but postpone it, thus reducing the initial investment costs.

How to have a resilient approach/response to the problem, trying to prefigure concrete and not–often–utopian scenarios for the achievement of urban-territorial transformations? Some recent publications deal both with the multidisciplinary and complex nature of urban resilience [18,19] and with the measures for the resilient city of the future [20,21]. If, on the one hand, the higher costs of intervention due to the site reclamation need important public actions to increase the attractiveness of these transformations (reduction of urbanization costs, greater volume, etc.), on the other hand, it is necessary that the municipalities address this issue without delaying a position because time will inevitably create social impacts. For all these reasons, the presented case study aims to verify how (economically and financially) possible the (resilient) scenario that specifically addresses the problem of decontamination related costs, showing all its resilience avoiding abandonment and producing green energy.

2. Materials and Methods

We considered an abandoned industrial area in Piedmont as a case study, aiming at verifying the financial and economic sustainability of a clean energy production intervention for municipal public use, postponing reclamation and recovery works (Table 1). The site chosen is located in the metropolitan area of Turin in a peripheral area in the south-west of Ciriè old town. On the site, there are the buildings that were once owned by a company which, after being the cause of over hundreds death from bladder cancer, closed in 1982 (Figures 2–4). Then, a more recent company owned the area and crammed large quantities of toxic waste inside the buildings, generating a heavy pollution of the entire underground site. After that, the area was purchased by the Town Council for about 335,697.00 €. At the end of 1990s, a first surface decontamination was carried out thanks to a Ministry funding of about 3,098,741.00 € [17]. However, the subsoil reclaim has still to be carried out. The possible types of land reclamation work span from surface capping to excavation and disposal. Depending on the type of intervention, the costs are very different. In the hypothesis, to carry out the simplest (superficial capping), the cost would be approximately 1.500.000,00 €, or 75 €/m^2 [2]. With regard to the considerable costs associated with land reclamation works, it is assumed these can be deferred over time (or not supported at all) and postponed until retrieve the area to make it permanently stable again.

Table 1. Case study main quantitative data.

Quantitative Data					
$\mathbf{S_{territorial}}$	20,531	m^2	$\mathbf{V_{bad\ state\ buildings}}$	31,983.4	m^3
$\mathbf{i_{coverage}}$	0.514	-	$\mathbf{V_{medium\ state\ buildings}}$	56,905.1	m^3
$\mathbf{V_{total\ buildings}}$	105,969.2	m^3	$\mathbf{V_{good\ state\ buildings}}$	17,080.7	m^3

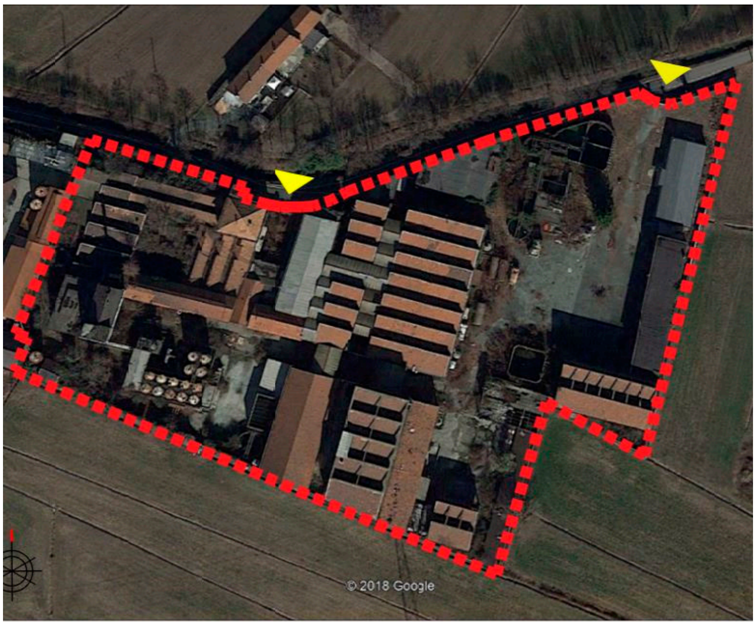

Figure 2. The area [22].

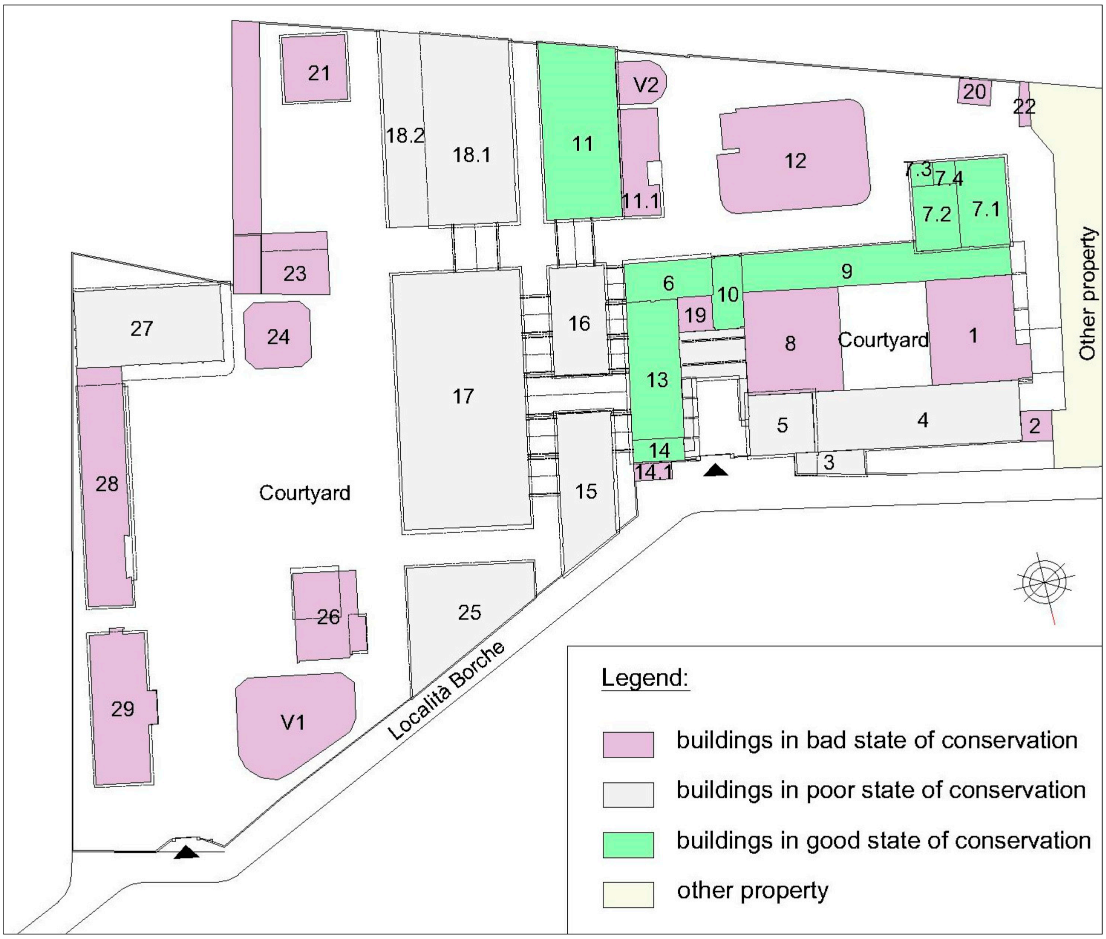

Figure 3. The case study representation of buildings and their state of conservation (plan by the authors on the basis of cartographic data provided by the municipality).

Figure 4. The area from outside [22].

Assuming that the area can be used for energy production, to supply part of the public administration's needs, some further clarifications are required. First, it is assumed the town administration provides demolition of the dilapidated buildings, thus achieving a clearance of part of ground. Second, we can create a photovoltaic field within the town using the free areas of the site and building roofing that were put in safe to partially compensate for the electricity needs of public users (schools, malls, etc.) without land consumption [23,24]. All this, without any interference with the polluted ground, is possible through the use of a very light system to secure the photovoltaic supporting frame to the ground without excavation (Figures 5 and 6).

Figure 5. The selected photovoltaic panels' support module [25].

Figure 6. The module anchoring system to the ground [25].

The financial assessment of the investment was evaluated according to the scheme shown in Figure 7.

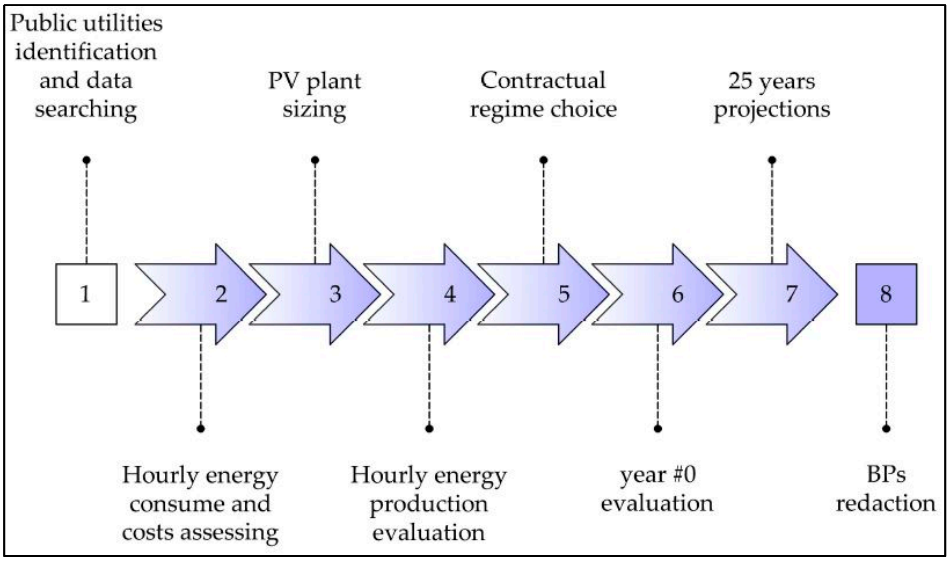

Figure 7. Graphic representation of method evolution.

The first step was to identify the public utilities whose electrical requirements have to be partially met and to find the necessary data for these. From these, an approach was constructed, which allowed us to estimate the users' electricity consumption of each hour of a type of day. Then, the photovoltaic field was sized and the daily average production of electricity was estimated with reference to a type of day of each month of the year. A procedure to estimate the electricity produced by the photovoltaic field from hour to hour over a type day was developed and the contractual regime to be established between the public administration and the manager of energy services (GSE) was chosen. After that, relatively about a referenced time (year #0), the quantities of energy requested and consumed by the users themselves and the quantities of energy fed into the grid was determined on the basis of two opposing hypotheses: It is possible/not possible to self-consume the energy produced by the photovoltaic field. Twenty-five-year projections were drawn up, on the basis of the obtained data, to identify the variation in the above quantities of energy based on two assumptions: That the annual electricity demand will be always constant and equal to that defined for year #0, and that there will be a decline in annual producibility of 0.75% starting from year #0. Therefore, the revenues for year #0 were defined because they derive from the feeding into the grid of electricity produced by the photovoltaic field and/or by the self-consumption of energy. Twenty-five-year projections were drawn up starting from the costs related to the purchase of energy, identified for the year #0 of reference, on the basis of two different cases: That the costs will be the same of the year #0 for the years to come, and that the costs of energy will be increased of 2.5% from year #1 onwards. Then, the costs of the plant were calculated, as well as the operating costs (insurance, ordinary and extraordinary maintenance) and the costs relating to the contract with the energy services manager (GSE) for the year #0. After that, even in this case, 25-year projections were carried out assuming two different cases: That the operating costs will be constant over the years, and that the operating costs will undergo annual inflation of 2%. At this point, according to four different hypotheses, four different BPs were drawn up to check the investment sustainability.

3. Results

In the municipality, the public utilities are distributed on the territory and are identified by 43 points of electrical delivery relative to: 14 housing, one library, one day-care center, two nursery schools, four elementary schools, two high schools, one grammar school, three malls, five wells and fountains, one joint accommodation, a public toilet, two performing areas, five security cameras, and one local police command. As there no files available about electricity bills, the city technical office expense estimation was assumed together with the power characteristic of each user.

The Italian Electricity, Gas, and Water Authority (AEEGSI) publishes quarterly tables on electricity fares for users on the economic conditions of highest security service. These fares vary depending on whether the power delivery point is for a "domestic use" or "other use;" and on the appointed power and maximum power available [26].

The appointed power is the level of power stated by contracts, defined according to the customer's requirements at the contract time and depending on the type and number of electrical appliances currently on. Instead, the maximum available power is the level above, in which there is an automatic shut off of the electricity delivery. Thus, assuming that the utilities considered in this case of study are all subjected to the economic conditions of highest security service, we considered each appointed power (PI), the max available power (PD), and the fares applied (CT). Therefore, it was possible to track back to the true annual cost for electricity of each user. Each AEEGSI table is organized as matrix: The rows contain the energy cost, the flat fare, and the power dispatch. On the columns, however, there are three macro sectors that are sales services, network services, and general system charges. Each of that is, in turn, composed of a certain number of items for which a specific cost is defined [27].

Taxes do not apply to values on the tables just mentioned, so in order to obtain the final expense, VAT and VAT rates have to be identified and added to the bill. On this matter, even in this case, the values are provided by AEEGSI in tabular form. In the case of study, all the points of delivery ("POD") are of "Low Voltage Other Uses" kind as the annual consumption for each point is less than 200,000 kWh per annum, the duty tax is equal to 1.25 cent €/kWh [28], while VAT is 22% for 42 utilities and 10% only for one of them. Another issue involved in energy billing is the power timing (peak/off-peak hours). We had no data, but as we are mostly dealing with housing and schools, it was possible to hypothesize:

- The great part of electricity consumption takes place from Monday to Friday between 8:00 and 18:00, (peak hours, F1 price);
- The estimated average monthly consumption (CMS) derives from the equal divide of the estimated annual average consumption (CAS) in 12 (months of the year). It should be noted that the CMS is defined depending on the power day timing schedule. However, the hypothesis assumed above implies the estimated average month consumption off peak (F2 + F3) is negligible, while the most part of the power is in the peak hours (F1).

In each transaction, for each point of delivery, the costs of sales services, network services, and duty for each of the three quotas on which each electric bill is made, namely the energy quota, the flat fare and the power dispatch were recorded. The value defined by the sum of the energy quota and the taxes is of paramount importance to evaluate the profitability of a photovoltaic field installation. This value was calculated as for VAT at the initial stage of overall cost assessment only instead in the subsequent economic considerations it is no longer taken into account because a turn-around between purchasing and selling energy under on-trade exchange is considered. Summing up the quantities obtained for each point of delivery, it is estimated that the municipality has to face a total year expenditure for electricity of about €200,000.00 (682,469 kWh) (Table 2). The parametric value of energy quota is 0.171 €/kWh.

Table 2. List of total annual costs due to the electricity requirements deriving from individual users.

List	€/Year	€/(kWh per Year)
Energy share	€107,983.45	€0.1582
Energy share + Fixed share + Power share	€156,388.63	€0.2292
Treasury tax	€8,530.86	€0.0125
Energy share + Treasury tax	€116,514.31	€0.1707
Energy share + Fixed share + Power share + Treasury tax	€164,919.49	€0.2417
Value added tax (I.V.A.)	€34,348.80	€0.0503
Energy share + Fixed share + Power share + Treasury tax + I.V.A.	€199,268.29	€0.2920

Each electricity bill, as seen before, is based on the value attributed to the kWh at the time of usage, and the 43 PODs were condensed into a unique fictitious one to achieve a simple calculation process. In this way, an hourly power schedule could be defined, taking it from the daily requirement of all the utilities, equal to 2700 kWh. Since the hourly energy quantities required by the fictitious POD actually depend on the real users' behavior, which is not known ex ante, it was necessary to assume a daily load profile to be applied to the typical customer.

This profile is composed on two functions: A constant, taking into account the plafond energy demand, and a variable, taking into account the power demand hour per hour. Through this profile, the different amount of energy required by the fictitious POD "all-utilities" was obtained. In Table 3, wn the value concerning: average percentage required power (PPM_R), peak hourly required energy (EOP_R), average hourly required energy (EOM_R), hourly required energy (EO_R), and percentage of required energy in one hour compared to the total of the day (% E_{R_ToT}) are shown.

Table 3. List of electricity required for each hour of the day from the fictitious sampling point.

	Hours											
	7	8	9	10	11	12	13	14	15	16	17	18
PPM_R [%]	0	100	75	50	25	0	0	25	50	75	100	0
EOP_R [kWh]	0	338.5	253.9	169.3	84.6	0.0	0.0	84.6	169.3	253.9	338.5	0
EOM_R [kWh]	0	101.6	101.6	101.6	101.6	101.6	101.6	101.6	101.6	101.6	101.6	0
EO_R [kWh]	0	440.1	355.5	270.8	186.2	101.6	101.6	186.2	270.8	355.5	440.1	0
E_{R_ToT} [%]	0	16	13	10	7	4	4	7	10	13	16	0

Using a simple tool for preliminary photovoltaic panel evaluation, the photovoltaic system was drafted. We planned 38 rows of 18 photovoltaic modules (285 W peak output each) inclined by 30° compared to the horizontal (and exposed to the south). They work together with a 200 kW inverter, aiming toward a total peak output of about 195 kW. The software simulation considers the solar radiance month by month, so we obtain the average amount of electricity produced monthly. This value is supposed equally divided on each day of the relative month, giving the typical daily production for each month and the average daily area production (Table 4).

Table 4. Monthly average produced energy (Em_p), daily average produced energy (Eg_p), and daily average produced energy per square meter of photovoltaic panel (Egm_p).

Months	Em_p [kWh]	n° Days	Eg_p [kWh]	Fotovoltaics Field [m^2]	Egm_p [kWh/m^2]
January	10,104.2	31	325.9	1340	0.2432
February	13,610.6	28	486.1	1340	0.3628
March	21,788.2	31	702.8	1340	0.5245
April	22,822.7	30	760.8	1340	0.5677
May	24,848.5	31	801.6	1340	0.5982
June	25,605.8	30	853.5	1340	0.6370
July	26,930.7	31	868.7	1340	0.6483
August	25,023.4	31	807.2	1340	0.6024
September	20,885.7	30	696.2	1340	0.5195
October	18,339.6	31	591.6	1340	0.4415
November	13,068.2	30	435.6	1340	0.3251
December	10,196.1	31	328.9	1340	0.2455

Assessing the needed area, the main goal was not to perturbate the ground to build foundation for supporting the rows of photovoltaic panels. Any excavation would have produced amount of polluted ground to be decontaminated before its transfer to a landfill site. On the other hand, in Italy, a lightly polluted site can be used if there is not any continued human presence and if the soil is left untouched [2]. In this frame, the support system for the photovoltaic panels that resulted in low compliance consists of four vertical elements linked by two brace elements and in four horizontal elements, bearing the photovoltaic panels screwed on them. At the base of the support of the vertical elements, there are four tubular elements at 45°, which act also as a guide to give the right inclination to the 1.5 m long bars which were once fixed into the ground by means of am electro pneumatic hammer. This guarantees the anchoring of the entire module. This system is inspired to the anchoring modalities of tree roots [25].

Concerning the photovoltaic billing option, we assumed the public administration's best choice is the onsite exchange, and in this eventuality, we proceeded to a more detailed analysis. We determined the amplitude of each solid angle is crucial, as we assumed this is directly proportional to the photovoltaic panel hourly production to assess the economic viability of this simulation. Using solar cards, it was possible to outline a photovoltaic panel sun exposure in a typical day for each month, and thus to define the solid angles of the sun rays hour per hour. These angles are functions of azimuth angles and solar heights singled out by the sun during its daily journey as tabulated on solar maps. Considering the distance between this photovoltaic field and all the PODs (points of power delivery) and the opportunity to establish onsite exchange system (SSP) [29] with the Italian Energy Services Manager (GSE), two different scenarios were suggested:

i. Scenario A: Concurrent energy self-consumption is possible;
ii. Scenario B: The photovoltaic production is transferred to the energy network and then delivered later to the users.

Referring to similar studies [30–33], we summarized the economic analyses below considering the initial situation (year #0) in which all the energy involved comply with the two scenarios previously hypothesized: By determining the users energy demand and the photovoltaic panel performance hour by hour, it was possible to calculate the electricity to and from the network beside the self-consumed quota in each period (Tables 5 and 6) At last, the quantities for peak and off-peak time were summed to obtain, for the year #0, the values of the yearly energy network demand and of the consume quota (Tables 7 and 8).

Table 5. Energy volume.

Scenario A-Year #0								
Energy Peak and Off-Peak Time								
F1 Band			**F2 Band**			**F3 Band**		
$\mathbf{E_r}$	682,469.0	kWh	$\mathbf{E_r}$	0.0	kWh	$\mathbf{E_r}$	0.0	kWh
$\mathbf{E_{prod}}$	159,031.5	kWh	$\mathbf{E_{prod}}$	35,541.0	kWh	$\mathbf{E_{prod}}$	38,651.3	kWh
$\mathbf{E_{taken}}$	536,979.3	kWh	$\mathbf{E_{taken}}$	0.0	kWh	$\mathbf{E_{taken}}$	0.0	kWh
$\mathbf{E_{in}}$	−13,541.9	kWh	$\mathbf{E_{in}}$	−35,541.0	kWh	$\mathbf{E_{in}}$	−38,651.3	kWh
$\mathbf{E_{self\ c.}}$	145,489.7	kWh	$\mathbf{E_{self\ c.}}$	0.0	kWh	$\mathbf{E_{self\ c.}}$	0.0	kWh

Table 6. Energy volume.

Scenario B-Year #0								
Energy Peak and Off-Peak Time								
F1 Band			**F2 Band**			**F3 Band**		
$\mathbf{E_r}$	682,469.0	kWh	$\mathbf{E_r}$	0.0	kWh	$\mathbf{E_r}$	0.0	kWh
$\mathbf{E_{prod}}$	159,031.5	kWh	$\mathbf{E_{prod}}$	35,541.0	kWh	$\mathbf{E_{prod}}$	38,651.3	kWh
$\mathbf{E_{taken}}$	682,469.0	kWh	$\mathbf{E_{taken}}$	0.0	kWh	$\mathbf{E_{taken}}$	0.0	kWh
$\mathbf{E_{in}}$	159,031.5	kWh	$\mathbf{E_{in}}$	35,541.0	kWh	$\mathbf{E_{in}}$	38,651.3	kWh
$\mathbf{E_{self\ c.}}$	0.0	kWh	$\mathbf{E_{self\ c.}}$	0.0	kWh	$\mathbf{E_{self\ c.}}$	0.0	kWh

Table 7. Total energy volume.

Scenario A		
Total for Year #0		
$\mathbf{E_{r\text{-}TOT}}$	682,469.0	kWh
$\mathbf{E_{prod\text{-}TOT}}$	233,223.8	kWh
$\mathbf{E_{taken\text{-}TOT}}$	536,979.3	kWh
$\mathbf{E_{in\text{-}TOT}}$	87,734.1	kWh
$\mathbf{E_{self\ c.\text{-}TOT}}$	145,489.7	kWh

Table 8. Total energy volume.

Scenario B		
Total for Year #0		
$\mathbf{E_{r\text{-}TOT}}$	682,469.0	kWh
$\mathbf{E_{prod\text{-}TOT}}$	233,223.8	kWh
$\mathbf{E_{taken\text{-}TOT}}$	682,469.0	kWh
$\mathbf{E_{in\text{-}TOT}}$	233,223.8	kWh
$\mathbf{E_{self\ c.\text{-}TOT}}$	0.0	kWh

Each scenario leaded to two different results. The energy produced by the photovoltaic panel represents 34% of global demand in both scenarios, while the self-consumed quota is 21% in scenario A and drops to 0% in scenario B.

Acquiring these data for year #0, 25-year projections were made, assuming the annual electricity demand being constant through the decades and an annual productivity decay of 0.75%. The revenues deriving from the photovoltaic panel installation depend on two factors: The GSE exchange money contribution, and the savings due to the self-consumed quota. In scenario A, the first is worth about 13,000.00 €, while in scenario B, it is worth about 36,000.00 €. The difference between the two values is due to the fact that in the scenario B, the electricity produced by the photovoltaic plant is directly given into the electric network, while in scenario A, a quota of this energy is self-consumed.

Considering a cost of a 0.17 €/kWh (duties included), the self-consumption energy results equal 25,000.00 € savings. To assess the economic soundness of the investment, two 25-year simulations were made according to the two different hypotheses above summarized. In the first, all the electricity costs of remain the same as those of the year #0, while in the second, we assumed an annual increase of 2.5%.

The "turnkey cost" of a photovoltaic system with powers from 20 to 200 kW is about 1300 €/kWp, so the initial investment in the case under consideration includes an outlay of 253,500.00 € [34]. These costs, which include the purchase of photovoltaic modules, inverters, support structures, electrical equipment, design, and installation, are all concentrated in the startup time. Then, we have the management expenditure (insurance, ordinary, and extraordinary maintenance [35]). A local survey shows 6.50 €/kWp insurance cost, while we have to consider an average yearly extraordinary maintenance costs of 0.75% of the initial expenses.

Every 10 years, the inverters are expected to be replaced. This item changes by about the 10% of the initial cost. Last, each year, GSE will have to be paid for activating the SSP: In Italy, the fixed fee (30 €/year), the connection point fee (45 € for each PODs, 43 in total), and the variable fee of 1 €/kW (175.00 € because the first 20 kW are considered in the fixed fee). Twenty-five-year projections based on two different hypotheses were also made for management costs: One that assumes that costs constant (hypothesis 1), and the other, where it is assumed instead that they undergo an inflation of 2% per annum (hypothesis 2). All considered, we have four different financial economic plans [36] (Table 9).

Table 9. Summary assumptions for each calculated business plan (BP).

BP	Savings for Self-Consumption	Exchange Account Contribution	Energy Inflation Rate (2.5%)	Costs Inflation Rate (2%)
1	☑	☑	☒	☒
2	☑	☑	☑	☑
3	☒	☑	☒	☒
4	☒	☑	☑	☑

Assuming that the municipality is directly involved in the investment by its own capital of approximately €78,500.00 (30% of the total cost of the plant), while the difference (about 180,000 €) is founded by a 20-year mortgage loan at a rate of 2.60% [37]. An annual depreciation of 4% will apply [38]. Every year, the Regional Tax on Productive Activities must be paid (8.5%) on the tax base.

4. Discussion and Conclusions

In order to evaluate the profitability of the intervention, it is necessary to define an index that represents the weighted average cost of money, WACC [39,40]. This index is estimated at 5.42% and expresses the minimum acceptable return to find the proposed investment economically acceptable.

By calculating cash flows for each BP and discounting them at the defined discount rate (5.42%), the net present value (NPV) is obtained. Once calculated, the internal rate of return (IRR), a positive NPV, and the calculated value for the IRR greater than that calculate WACC must have been achieved to consider the investment acceptable. By performing the calculations described above in all the four financial plans previously prepared, the results are shown in the following table.

Looking at the Table 10, it can be seen that only BP#2 and BP#4 would be acceptable, i.e., those that provide for an annual update of the cost of energy and management costs by applying the 2.5% rate for the first and 2% for the second. BP#1 and BP#3 appear to be unacceptable, as the NPV is negative and the IRR is lower than the WACC. However, even considering the worst (BP#3), imposing a WACC equal to the IRR would result in the current net value (NPV) to zero. As previously stated, the plant does not result in any increase in profit. However, even in this case, looking at the investment from the environmental point of view, it actually brings a benefit by avoiding the release of large amounts of carbon dioxide, about 2833 tons in 25 years. So, even if the hypothesis that leads to BP#1 and BP#3 occurs, the investment would still be environmentally sustainable, which is now requested in Italy by law for all public works as a result of the application of the minimum environmental criteria [41].

Table 10. Summary of WACC, NPV, and IRR final values for each Business Plan (BP) drawn up.

	BP#1 (25 Years)	BP#2 (25 Years)	BP#3 (25 Years)	BP#4 (25 Years)
WACC	5.42%	5.42%	5.42%	5.42%
NPV	−€17,111.80	€95,651.20	−€36,840.75	€45,365.27
IRR	4.7%	8.7%	3.8%	7.1%

The investigated scenario (redevelopment for energy production) aims, when possible, to partially respond to the main critical issues related to the process of brownfield regeneration [42–44], achieving two goals at the same time: Not consuming land for new plants and helping to reduce costs incurred by the municipality for public services (schools, lighting, etc.).

Analyzing current paper on brownfield [11,43–45], we can say that literature, in many cases, covers statistically definitions of parameters or indicators from a large dataset (land remediation costs, local actor role in re-development, policies need, etc.). Some single-case studies lead, instead, to scenarios of re-naturalization [46–48], that, mainly in inner-city sites, is more utopian than what the paper has prefigured. As recent similar case studies [42,49,50], the research is carrying on analyzing possible forms of public private partnership (PPP) in order to verify how to involve private capital for this urban transformation. In order to overcome the distance between public finance and private investments [51], the economic and financial convenience of real estate transformations in neighboring areas is also currently verifying to determine whether, through a convention, the private developer can carry out specific interventions (instead of requested urbanization costs) on the buildings area fence wall and on the soil, allowing the placement of monitoring probes for soil pollution levels.

In conclusion, the higher costs of intervention due to the site reclamation need important public actions to increase the attractiveness of these transformations: Otherwise, a real estate developer will always choose–on an equal basis of attractiveness–those areas with the lowest related costs in order to increase his profit. So, it is necessary that the municipalities address this issue without delaying a position, promoting–as done by large metropolitan cities around the world [20]–resilient tools and strategies for planning future direction.

Future developments of the research aim at testing the method on the largest sample of brownfield in the metropolitan area, classifying the plots by similarities, and, for homogeneous subsets, verifying the technical and economic-financial feasibility of different intervention alternatives (reconversion, energy production, re-naturalization, etc.).

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References

1. Rosella, C. *Corso di Storia Generale*; Lulu Press: Morrisville, NC, USA, 2009; ISBN 9781409293545.
2. Sandrone, C.; Carboni, M.; Goria, P. (TRS Servizi Ambiente s.r.l. Company, Piacenza, Italy). Criteri di Definizione degli Interventi di Bonifica in Considerazione dei Possibili Scenari di Sviluppo Delle Aree, Personal Communication, AUDIS Conference. 8 July 2009. Available online: http://audis.it/dall-associazione/audis-e-il-recupero-dei-brownfields-il-convegno-dell-8-luglio-in-collaborazione-con-dla-piper-e-gruppo-trs-i-materiali/ (accessed on 15 March 2019).
3. Fabian, L.; Munarin, S. (Eds.) *Re-Cycle Italy—Atlante*; LetteraVentidue Edizioni: Siracusa, Italy, 2017; pp. 35–121. ISBN 9788862422000.
4. Piantanida, P.; Rebaudengo, M. The construction sector crisis in Italy: Any strategy for small and medium-sized builders? In *Proceedings of the 4th International Multidisciplinary Scientific Conference on Social Sciences and Arts SGEM 2017*; STEF92 Technology Ltd.: Sofia, Bulgaria, 2017; Book 5; Volume 2, pp. 759–766. ISBN 978-619-7408-25-6. Available online: https://sgemsocial.org/ssgemlib/spip.php?article4966 (accessed on 15 March 2019). [CrossRef]
5. Abu Raed, A. Rehabilitation of industrial sites: Economical and social aspects. *J. Eng. Appl. Sci.* **2018**, *13*, 5688–5690. [CrossRef]
6. Gegic, A.; Husukic, E. Evaluation of the Brownfield regeneration process: Case study of Sarajevo, Bosnia and Herzegovina. *J. Urban Regen. Renew.* **2017**, *10*, 276–285.
7. Moscovici, A.-M.; Banescu, O.-A.; Vaduva, R. Integrating brownfield sites into city redevelopment strategies. In Proceedings of the 17th International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM, Albena, Bulgaria, 27 June–6 July 2017; Volume 17, pp. 675–682. [CrossRef]
8. Wcisło, E.; Bronder, J.; Bubak, A.; Rodríguez-Valdés, E.; Gallego, J.L.R. Human health risk assessment in restoring safe and productive use of abandoned contaminated sites. *Environ. Int.* **2016**, *94*, 436–437. [CrossRef] [PubMed]
9. Clark, C.M. Drosscapes or Brownfields? Differing processes to bring redundant industrial land, including military sites, back into productive use. *WIT Trans. Ecol. Environ.* **2009**, *120*, 181–185.
10. Bell, F.G.; Genske, D.D.; Bell, A.W. Rehabilitation of industrial areas: Case histories from England and Germany. *Environ. Geol.* **2000**, *40*, 121–123. [CrossRef]
11. Chen, I.-C.; Chuo, Y.-Y.; Ma, H.-W. Uncertainty analysis of remediation cost and damaged land value for brownfield investment. *Chemosphere* **2019**, *220*, 371–380. [CrossRef] [PubMed]
12. Agenzia per la Protezione Dell'ambiente e per i Servizi Tecnici (APAT). *Proposta di Line Guida per il Recupero Ambientale e la Valorizzazione Economica dei Brownfields*; IGER: Roma, Italy, 2006; ISBN 88-448-0219-8.
13. CLARINET Consortium. *Brownfields and Redevelopment of Urban Areas*; European Union: Brussels, Belgium, 2002; Available online: http://www.eugris.info/displayresource.aspx?r=6397 (accessed on 15 March 2019).
14. ANCI. Disegno di Legge Recante Misure per Favorire la Riconversione e la Riqualificazione Delle Aree Industriali Dismesse. 2015. Available online: http://leg17.senato.it/leg/17/BGT/Schede/Ddliter/documenti/45431_documenti.htm (accessed on 15 March 2019).
15. Web Site Progetto Trentametro—Città Metropolitana di Torino. Available online: www.cittametropolitana.torino.it/cms/attivita-produttive/attrazione-investimenti/trentametro/ (accessed on 15 March 2019).
16. Rosato, P. The Value of Building Plots in Italy. Territorio Italia—Land Administration, Cadastre, Real Estate. 2014, Volume 2, pp. 13–15. Available online: https://arts.units.it/handle/11368/2836238#.XLWoAuIRWUk (accessed on 15 March 2019). [CrossRef]
17. Borello, F. L'IPCA: I 168 Colori Della Morte. 2016. Available online: https://piemontefantasma.wordpress.com/2014/05/18/lex-ipca-ed-i-colori-della-morte/ (accessed on 15 March 2019).
18. Jabareen, Y. Planning the resilient city: Concepts and strategies for coping with climate change and environmental risk. *Cities* **2013**, *31*, 220–229. [CrossRef]
19. Meerow, S.; Newell, J.P.; Stults, M. Defining urban resilince: A review. *Landsc. Urban Plan.* **2016**, *147*, 38–49. [CrossRef]
20. Jabareen, Y. An assessment framework for cities coping with climate change: The case of New York City and its PlaNYC 2030. *Sustainability* **2014**, *6*, 5898–5919. [CrossRef]

21. Jabareen, Y. *The Risk City. Cities Countering Climate Change: Emerging Planning Theories and Practices around the World*; Springer: Berlin, Germany, 2015; ISBN 978-94-017-9768-9.
22. Google Map. Available online: https://www.google.com/maps (accessed on 9 October 2018).
23. Poggi, F.; Firmino, A.; Amado, M. Assessing energy performances: A step toward energy efficiency at the municipal level. *Sustain. Cities Soc.* **2017**, *33*, 57–69. [CrossRef]
24. Lee, J.; Chang, B.; Aktas, C.; Gorthala, R. Economic feasibility of campus-wide photovoltaic systems in New England. *Renew. Energy* **2016**, *99*, 452–464. [CrossRef]
25. Tree System Srl Website. Dispositivi di Ancoraggio, Struttura a Terra Fissa di Supporto Moduli Fotovoltaici Mono e Doppio Pannello Verticale, Padova, Italy. Available online: www.treesystem.it/struttura-fotovoltaica-mono-pannello (accessed on 9 October 2018).
26. Italian Electricity, Gas and Water Authority (AEEGSI) Website. Autorità di Regolazione per Energia Reti e Ambiente, Condizioni Economiche per i Clienti del Mercato Tutelato, 2015 Spreadsheet. Available online: https://www.arera.it/it/dati/condec.htm (accessed on 9 October 2018).
27. Italian Electricity, Gas and Water Authority (AEEGSI) Website. Autorità di Regolazione per Energia reti e Ambiente, Bolletta 2.0. Available online: https://bolletta.arera.it/bolletta20/index.php/guida-voci-di-spesa/elettricita (accessed on 9 October 2018).
28. Italian Electricity, Gas and Water Authority (AEEGSI) Website. Autorità di Regolazione per Energia reti e Ambiente, Imposte Sull'energia Elettrica, 2014 Spreadsheet. Available online: https://www.arera.it/it/dati/eep38.htm (accessed on 9 October 2018).
29. Italian Energy Services Manager (GSE) Website. Gestore dei Servizi Energetici, Scambio Sul Posto. Available online: https://www.gse.it/servizi-per-te/fotovoltaico/scambio-sul-posto/chi-pu%C3%B2-accedere (accessed on 9 October 2018).
30. Palmer, J.; Sorda, G.; Madlener, R. Modeling the diffusion of residential photovoltaic systems in Italy: An agent-based simulation. *Technol. Forecast. Soc. Chang.* **2015**, *99*, 108–120. [CrossRef]
31. Battisti, R.; Corrado, A. Evaluation of technical improvements of photovoltaic systems through life cycle assessment methodology. *Energy* **2005**, *30*, 952–967. [CrossRef]
32. Spertino, F.; Di Leo, P.; Cocina, V. Economic analysis of investment in the rooftop photovoltaic systems: A long-term research in the two main markets. *Renew. Sustain. Energy Rev.* **2013**, *28*, 531–540. [CrossRef]
33. Chiaroni, D.; Chiesa, V.; Colasanti, L.; Cucchiella, F.; D'Adamo, I.; Frattini, F. Evaluating solar energy profitability: A focus on the role of self-consumption. *Energy Convers. Manag.* **2014**, *88*, 317–331. [CrossRef]
34. Politecnico di Milano—Dipartimento di Ingegneria Gestionale, Solar Energy Report. 2014. Available online: http://www.energystrategy.it/ (accessed on 9 October 2018).
35. Rebaudengo, M.; Piantanida, P. Maintenance of buildings: Italian examples of deviations between planned and incurred costs. In *IOP Conference Series: Materials Science and Engineering*; IOP Publishing: Bristol, UK, 2017; Volume 351, pp. 1–5. [CrossRef]
36. Mecca, U. Impatto Delle Aree Dismesse Sulla Produzione di Energia Locale. Il Caso del Fotovoltaico: Sostenibilità di un Possibile Intervento sul sito Dell'ex Area Industriale I.P.C.A. a Ciriè. Master's Thesis, Politecnico di Torino, Turin, Italy, 2016.
37. Italian Ministry of Economy and Finance Website. Ministero dell'Economia e delle Finanze—Dipartimento del Tesoro, Coefficienti di Indicizzazione dei btp con Base 15/09/2015 (Report). Available online: www.dt.tesoro.it/it/debito_pubblico/dati_statistici/coefficienti_indicizzazione_15_03_11_15anni/ (accessed on 9 October 2018).
38. Italian Revenue Agency Website, Agenzia delle Entrate, Circolare 36/2013—Ammortamento Fotovoltaico e Eolico. Available online: https://www.agenziaentrate.gov.it/wps/content/Nsilib/Nsi/Normativa+e+Prassi/Circolari/Archivio+circolari/Circolari+2013/Dicembre+2013/?page=normativa (accessed on 9 October 2018).
39. Farber, A.; Gillet, R.L.; Szafarz, A. A General Formula for the WACC. *Int. J. Bus.* **2006**, *11*. Available online: https://ssrn.com/abstract=898420 (accessed on 15 March 2019).
40. Fernández, P. A More Realistic Valuation: APV and WACC with Constant Book Leverage Ratio IESE Business School Working Paper No. 715. 2007. Available online: https://ssrn.com/abstract=946090 (accessed on 15 March 2019).
41. Manzone, F.; Rebaudengo, M.; Zaccaro, V.L. The Italian Response to Sustainability in Built Environment: The Match between Law and Technical Assessment. In *Third International Congress on Information and Communication Technology*; Springer: Singapore, 2019; pp. 527–537. [CrossRef]

42. Ahmad, N.; Zhu, Y.; Shafait, Z.; Sahibzada, U.F.; Waheed, A. Critical barriers to brownfield redevelopment in developing countries: The case of Pakistan. *J. Clean. Prod.* **2019**, *212*, 1193–1209. [CrossRef]
43. Lin, H.-L.; Zhu, Y.-M.; Ahmad, N.; Han, Q.-Y. A research framework of conflict complexity for brownfield redevelopment: A social network perspective. In Proceedings of the International Conference on Management Science and Engineering—Annual Conference Proceedings, Nomi, Japan, 17–20 August 2018; IEEE: Piscataway, NJ, USA, 2018; pp. 263–268.
44. Dillmann, O.; Beckmann, V. Do administrative incentives for the containment of citieswork? An analysis of the accelerated procedure for binding land-use plans for inner urban development in Germany. *Sustainability* **2018**, *10*, 4745. [CrossRef]
45. Journel, C.M.; Gay, G.; Ferrieux, C.; Le Noan, R. Soil Pollution as an Industrial Heritage. from Indifference to Resilience? [Article@La pollution industrielle des sols en héritage. De l'indifférence à la résilience?]. *Houille Blanche* **2018**, *2018*, 20–26. [CrossRef]
46. Song, Y.; Kirkwood, N.; Maksimović, Č.; Zhen, X.; O'Connor, D.; Jin, Y.; Hou, D. Nature based solutions for contaminated land remediation and brownfield redevelopment in cities: A Review. *Sci. Total Environ.* **2019**, *663*, 568–579. [CrossRef] [PubMed]
47. Li, X.; Bardos, P.; Cundy, A.B.; Harder, M.K.; Doick, K.J.; Norrman, J.; Williams, S.; Chen, W. Using a conceptual site model for assessing the sustainability of brownfield regeneration for a soft reuse: A case study of Port Sunlight River Park (U.K.). *Sci. Total Environ.* **2019**, *652*, 810–821. [CrossRef]
48. Maantay, J.A.; Maroko, A.R. Brownfields to greenfields: Environmental justice versus environmental gentrification. *Int. J. Environ. Res. Public Health* **2018**, *15*, 2233. [CrossRef] [PubMed]
49. Morano, P.; Tajani, F. Saving soil and financial feasibility. A model to support public-private partnerships in the regeneration of abandoned areas. *Land Use Policy* **2018**, *73*, 40–48. [CrossRef]
50. Kiss, I.; Reith, A. Architectural and urban design tools for reducing energy consumption in cities. *Pollack Periodica* **2013**, *8*, 151–161. [CrossRef]
51. Caneparo, L.; Rolfo, D. From energy renovation to urban renovation: Tools for financing urban quality. *Territorio Italia—Land Administration, Cadastre, Real estate* **2017**, *1*, 97–116. [CrossRef]